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# THE USE OF THE ENTROPY MEASURE, *H*, AS AN INDEX OF PERCEPTUAL SIGN CODABILITY: A CROSS-CULTURAL STUDY[1]

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A cross-cultural and cross-linguistic experiment was reported in which the codability of perceptual signs was examined for three groups of *S*s with contrasting cultural and linguistic backgrounds, i.e., American, Finnish and Japanese. The results of the present study demonstrated that the entropy measure, *H*, is an adequate index of codability and that it can be applied not only to colors but also to forms, and for the subject groups differing both in culture and in language.

Brown and Lenneberg (1954) were able to demonstrate that, in naming colors, (1) the length of the name, (2) the quickness in naming, and (3) the agreement in naming, are good indices of what they term *codability*. They found that colors of highest codability occupy spatially central positions within the color regions named by eight familiar color names in English, i.e., Red, Orange, Yellow, Green, Blue, Purple, Pink, and Brown, and that colors in lowest codability always fall within transitional areas between any two such regions. Furthermore, to the extent that " the more codable categories of experience are also more available and that more codable stimuli are centrally located in available categories (Brown, 1958, p. 241) ", codability also appears to provide a useful index of cognitive familiarity.

The present work is an attempt to determine if the notion of codability can be applied not only to colors but also to forms. Our interest also lies in finding a new method by which the codability of colors and forms which we shall call *perceptual signs* in contrast to *linguistic signs*, can be indexed and compared across different languages used. For instance, a two-morpheme but single-word Japanese color name, *uguisu'iro*, (translating into English a bush-warbler color), is a *greenish brown* color for English. Thus, what is a phrase name for English and represents low codability according to the Brown-Lenneberg definition, may be a single-word name in a foreign language —an index of a high codable color. It is therefore evident that the Brown-Lenneberg definition of codability may not be applied to foreign languages with confidence.

In the present study, the notion of codability originally developed by the Brown-Lenneberg work on colors for English, was extended to line forms and to different languages, i.e., Finnish and Japanese, as well. The appropriateness of using a new

[1] The present study was planned and carried out as a part of the Research Project on Cross-Cultural Generality of Meaning Systems supported by the Society for the Investigation of Human Ecology in New York City, of which Dr. C.E. Osgood, Director of the Institute of Communications Research, University of Illinois, is principal investigator. The present author wishes to express his gratitude to Professor Osgood for his valuable suggestions on the research design, to Professor Torao Obonai of Nihon University for his reading of a preliminary draft of the present paper, and to Professor Martti Takala (now President) of the University of Jyväskylä for his assistance in data collection in Finland. Appreciation is also expressed to the University of Illinois Statistical Service Unit for the use of their facilities.

codability index, the entropy measure, $H$, was also cross-culturally examined. Finally, correspondence was investigated between codability and cognitive familiarity, using both color and form perceptual signs and for the three language/culture groups, i.e., American, Finnish, and Japanese.

## METHOD

*Subjects:* In order to assess the cross-cultural similarity, the experiment was run on three different groups of *Ss*—American, Finnish and Japanese—each representing a different language / culture base. The American *Ss* were 47 undergraduate and graduate students, both male and female, attending the University of Illinois, Urbana, Illinois. The Finnish *Ss* were 50 male and female undergraduates, attending the University of Jyväskylä, Jyväskylä, Finland. The Japanese *Ss* were 53 male and female undergraduates attending the Kuwazawa College of Arts and Design in Tokyo, Japan.

To avoid possible biases resulting from excessive exposure to foreign culture, it was desired that *Ss* be monolinguals, at least with respect to English, and have no experience with foreign language other than ordinary training in school. Each experimental group is assumed to be reasonably representative of each of the three sample languages and cultures, apart from the relatively high education level which was common to all groups.

*Stimulus materials:* The perceptual signs used as concepts in the experiment consisted of four colors and four line forms[2]. The selection of the concept stimuli was dictated by consideration of codability, an attempt being made to sample the range of high-codable and low-codable color and form alternatives. The concept stimuli selected to be used in the main experiment included two colors with high codability (Red and Green) and two colors with low-codability (Yellow Green and Red Purple), two high-codable line forms (Star and Circle) and two low-codable line forms (Nonsense Fingures mathematically generated).

The selection of these color and form stimuli followed these procedures ; first, for the colors, one color defining each of four highly codable regions, i.e., Red, Yellow, Green and Purple, were selected after the Brown-Lenneberg (1954) findings. That is, they demonstrated that well-known single-word color names such as Red were high-codable and centrally located, whereas the colors which occupy peripheral positions transitional between any two high-codable color regions were found to be low-codable. However, since there are many colors falling within each color region, it was necessary to determine which color best defines that region. Within each selected color region, therefore, several alternative colors were drawn from the Munsell color book (1929). A total of 34 colors was thus initially sampled from the eight color regions mentioned above—11 from the four high-codable and 23 from the four low-codable regions.

In selecting the representative colors and checking the cross-cultural agreement, four Americans, both male and female, four Japanese males, and a female Finn, all in resident at the University of Illinois, participated as informants, representing their respective language and culture. Somewhat different procedures were pursued in selecting high-codable colors and in selecting low-codable colors. First, in obtaining judgments of the 11 high-codable colors previously selected for the four high-codable color regions, alternative colors in the same region (e.g., Red) were shown to the informants in separate interviews. Then the informants were instructed to select the one which in their own opinion would best define each region. For the American and Japanese informants, the color names defining each color region were given in their own language, i.e., *aka*, *ki*, *midori* and *murasaki* for Japanese, corresponding with *red*, *yellow*, *green* and *purple* for English. For the Finn, the color names were first given in English and later it was confirmed

[2] The same data obtained from the three subject groups and used for the analyses reported in the present paper were also utilized, in a separate analysis, for testing the *congruity hypothesis* developed by Osgood et al. (cf. Osgood et al., *The measurement of meaning*. Urbana, Illinois: University of Illinois Press, 1957, p. 189 ff.) The sampling of stimulus perceptual signs as described above was thus dictated by consideration of the " congruity " analysis.

by the same informant that single-word names also exist in Finnish; that is, *purnainen* for red, *keltainen* for yellow, *vihreä* for green, and *purpura* for purple. Generally satisfactory concensus was reached among the nine informants as for four representative high-codable colors: R 4/14 as best representing Red, Y 8/12 as best representing Yellow, G 5/8 as best representing Green, and P 3/10 as best representing Purple.

Secondly, for the 23 low-codable colors selected from the four peripheral color regions, informants were told to give the color names of each in their own language. Now, considering "No Response" as well as the variety of different, translation-equivalent phrase names, such as *greenish yellow*, as an indication of low-codability, the following four colors were selected as representative of the four most low-codable color regions: YR 8/2 for Yellow Red, GY 8/2 for Yellow Green, PB 8/2 for Purple Blue and RP 6/2 for Red Purple.

Turning now to the line forms used in this study, those which have a definition in the form of definite form name were considered to be highly codable. Accordingly, Square, Circle and Star for English, or Nelikulmio, Ympyra and Tähti for Finnish, or Shikaku, Maru and Hoshi for Japanese, were selected as representative of such high-codable line forms, common to all three language/culture groups. On the other hand, three Nonsense Figures were generated mathematically, following the Atteneave-Arnoult (1956) method. Since such nonsense figures resemble meaningful figures only by chance and have no known name, they were considered as adequate representation of low-codable line forms, similarly so in all the three language/culture groups.

Following this initial choice of eight alternative colors and six alternative forms, the nine informants were intructed to rate these stimulus items on the seven-point *familiar-unfamiliar* semantic differential scale in their own language. It must be pointed out that, as described above, no direct examination of codability was made for the line forms, and it appeared necessary to confirm the assumed codability of these forms. If codability is related to *cognitive familiarity* as proposed by Brown (1958), the mean rating on the *familiar-unfamiliar* scale of each color and form should correspond with its assumed codability. Once this correspondence is demonstrated, a uniform base can be provided for both colors and forms by this familiarity measurement as equivalent of codability. The result of this familiarity check appeared to be quite satisfactory; that is, the high-codable concepts, both color and form, displayed high familiarity as compared with low-codable colors and forms. Every high-codable color was found to be *more familiar* than any low-codable color, and every high-codable form was found to be *more familiar* than every low-codable form. Within the high-codable color and form groups, Red and Green, as compared with Purple and Yellow, and Star and Circle, as compared with Square, were judged *more familiar* and therefore assumed to be more codable. Within the low-codable color and form groups, Red Purple and Yellow Green, as compared with Yellow Red and Purple Blue, and Nonsense Figures #1 and #2, as compared with Nonsense Figure #3, were found to be *more unfamiliar*, and therefore assumed to be more uncodable. It was therefore decided to use Red, Green, Red Purple and Yellow Green as colors, and Star, Circle, Nonsense Figures #1 and #2 as forms in the main experiment.

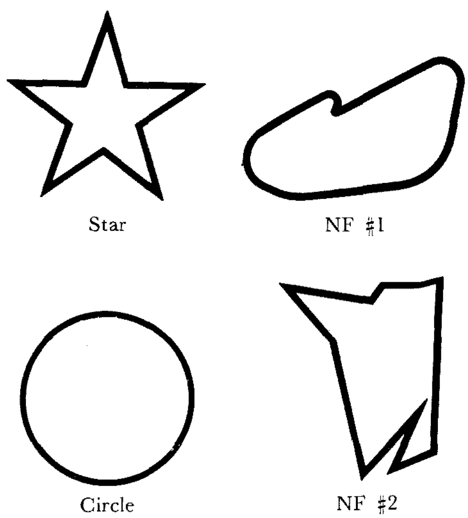
For the main experiment, the color materials having appropriate Munsell hues, values and chromas were obtained from the Allcolor, Co., Ltd., New York. The colors were presented by four color sheets, approximately $14 \times 20$ cm in size. The forms were drawn in black ink on thick white construction paper, approximately $20 \times 20$ cm in size. For the colors a neutral grey background paper (approximately 6.0/ in Munsell value) was used. For protection, all the stimulus materials were covered with a thin transparent polyethylene sheet. Munsell notations of colors and the actual line forms are displayed in Table 1.

*Procedure:* The main experiments were performed in Urbana, Illinois, U.S.A., in Jyväskylä, Finland, and in Tokyo, Japan. The eight stimuli were shown to the *S*s one by one. All the testings were performed in groups. The *S*s

TABLE 1
Stimulus materials used in the experiment

| Colors | Munsell Notations |
|---|---|
| Green | 5.0 G 5/8 |
| Red | 5.0 R 4/14 |
| Yellow Green | 5.0 YG 8/2 |
| Red Purple | 5.0 RP 6/2 |

Line Forms




in each subject group rated the four color and the four form concepts on the translation-equivalent *familiar-unfamiliar* scale (*tuttu-tuntematon* for Finnish and *najimiaru-najiminai* for Japanese) scale.[3] The order of the eight stimuli was constant for all the subject groups. Finally, in order to check the codability of color and form concepts, *S*s were shown each color and form once again and asked to " name " it in their own language.

[3] In fact, each *S* rated each of the eight perceptual signs and their 16 color/form combinations on a 10-scale form of semantic differential for testing the congruity hypothesis. These 10 semantic differential scales included 3 Evaluative, 3 Potency and 3 Activity translation-equivalent scales in addition to the *familiar-unfamiliar* scale. (cf. Y. Tanaka, A test of the congruity hypothesis across three language/culture communities. In *The Gakushuin Daigaku Seikei Gakubu Kenkyū Nenpō, No.* 9, *1962.*)

## CODABILITY OF COLOR AND FORM STIMULUS ITEMS

The color and form stimulus items used in the main experiments were selected as being presumably either codable (two colors and two forms), or uncodable (two colors and two forms). The results of the main experiments should, among other things, confirm the pre-test determinations.

A somewhat different approach to the measurement of codability was used in analyzing the main test results. The main reason for this procedural deviation from the pre-test was that we found the verbal labels associated with stimulus items not to be directly comparable across languages, and therefore the Brown-Lenneberg (1954) criteria for codability could not be used across languages with any confidence. For instance, Yellow Green in English is a phrase name, and consequently it represents low codability in itself according to the Brown-Lenneberg criterion. On the other hand, however, we found that several Japanese *S*s in the main experiment in fact gave more metaphorical but single-word names such as *uguisu'iro* (translating into English bush-warbler color) or *wakakusa'iro* (fresh grass color) for the same Yellow Green. Furthermore, the Japanese tended to use imported color names obviously borrowed from English, although they were all phonetically transcribed into Japanese *katakana*-form orthography. Sometimes, it was also noted that a three-morpheme Japanese word such as *ta'kak'kei* (many angled shape) has a two-morpheme English equivalent such as *poly'gon*. It would be however absurd to argue that the Japanese word represents lower codability than the English word having only two morphemes, although the Japanese lexeme can be decomposed into a greater number of morphemes.

One index that can be readily obtained is the entropy measure, *H*, which indexes the distributional characteristics of various events. Although the central problem in

the present investigation is concerned with the codability of perceptual signs, this $H$ measure can also be used First, elicitation of verbal names yields diversities and frequencies of terms in association with each perceptual sign. Secondly, the use of the entropy measure is quite consistent to the Brown-Lenneberg definition of codability, in that they, too, take account of the diversity factor in naming colors.

It will be recalled that each $S$ was requested to give a label for each color and form stimulus in the main experiment. If the codability of a stimulus is high, the diversity of labels should be relatively small, a few names having very high probability of occurrence, and hence $H$ should be small. On the other hand, if a stimulus has a low-codability, the diversity of labels should be relatively great, each name having relatively low probability of occurrence, and hence $H$ should be large. The maximum possible diversity occurs when each $S$ gives a different name, in which case codability is minimal, whereas the minimum possible diversity occurs when all $S$s give only one and the same name for the stimulus and codability is maximum.

Shannon's (1949, p. 19 ff.) information measure is given as:

$$-H(I) = \sum p(i) \log_2 p(i),$$

where $p(i)$ is the probability of the $i$th state, and where $(I)$ is the class of all states of the system. When names are elicited for a given stimulus, $p(i)$ is the obtained probability of each name elicited, and the formula gives the number of bits of information in the name-eliciting system. $H(I)$ is the expected value of the amount of uncertainty associated with each of the names elicited. If and only if all the $p(i)$'s but one are zero (i.e., all the $S$s give only one and identical name for the stimulus), $H$ becomes zero. On the other hand, for a given $N$ (viz., the number of $S$s), $H$ is maximum and equal to $\log_2 N$ when all the $p(i)$'s are equal to $1/N$—that is, when each of the $N$ $S$s gives a different name. In other words, the latter measure (symbolically $H_{max}$) represents the maximum degree of uncertainty when all states of a system are equally probable.

Since our final objective in this analysis is to compare the amount of uncertainty associated with each perceptual sign concept, we use the relative uncertainty, $H_{rel}$, which is the ratio of $H(I)$ to $H_{max}$; $H_{rel}$ varies from a minimum value of zero, when only one name is elicited and $H(I)$ is therefore zero, to a maximum value of one, when all the elicited names are different and equally probable and $H(I)$ is therefore equal to $H_{max}$. For our purpose, the diversity scores for each perceptual sign were obtained for each subject group, and $H_{max}$, $H(I)$, and $H_{rel}$ were respectively computed for each perceptual sign within each subject group. The results thus obtained are displayed in Table 2.

Codability defined in terms of $H_{rel}$ was found to vary from concept to concept, but it is always higher for the Green and Red colors and for the Star and Circle froms in every language/culture group than for the colors and forms selected as relatively unfamiliar. It is also clear that the familiar colors are less codable than the familiar forms used in this experiment, and similarly so in every subject group.

From inspecting the results of name-elicitation, some cross-culturally unique labelling behavior was also noted. For instance, Japanese $S$s tend to use a greater number of names in association with all color and form concepts. Especially for the color concepts, a greater diversity of color names was found, and this may be accounted for by the use of many imported foreign color names in addition to indigenous Japanese color names. Furthermore, in addition to greater availability of color names, both foreign and indigenous, it was also noted that the Japanese tend to use more metaphorical color names as compared with the American and Finnish $S$s. For instance, they gave phone-

TABLE 2

Codability of eight perceptual signs: The entropy measure, *H*.

| Concept | Diversity | $-H(I)$ | $-H_{rel}$ | Concept | Diversity | $-H(I)$ | $-H_{rel}$ |
|---|---|---|---|---|---|---|---|
| 1. American | | | | | | | |
| Green | 14 | 2.380 | 0.428 | Star | 3 | 0.296 | 0.053 |
| Red | 15 | 2.251 | 0.405 | Circle | 4 | 0.545 | 0.098 |
| Yellow Green | 23 | 3.885 | 0.699 | NF #1 | 41 | 5.248 | 0.945 |
| Red Purple | 30 | 4.456 | 0.802 | NF #2 | 28 | 4.712 | 0.848 |
| 2. Finnish | | | | | | | |
| Green | 12 | 1.874 | 0.332 | Star | 2 | 0.243 | 0.043 |
| Red | 12 | 2.014 | 0.357 | Circle | 2 | 0.328 | 0.058 |
| Yellow Green | 21 | 3.642 | 0.645 | NF #1 | 23 | 3.727 | 0.660 |
| Red Purple | 15 | 3.057 | 0.542 | NF #2 | 29 | 4.290 | 0.760 |
| 3. Japanese | | | | | | | |
| Green | 17 | 2.460 | 0.429 | Star | 5 | 0.536 | 0.094 |
| Red | 22 | 3.144 | 0.549 | Circle | 6 | 0.693 | 0.119 |
| Yellow Green | 36 | 4.918 | 0.859 | NF #1 | 44 | 4.987 | 0.871 |
| Red Purple | 35 | 4.815 | 0.841 | NF #2 | 27 | 4.307 | 0.752 |

1. $-H_{max} = \log_2 47 = 5.555$
2. $-H_{max} = \log_2 50 = 5.644$
3. $-H_{max} = \log_2 53 = 5.728$

TABLE 3

Mean familiarity of eight perceptual signs†

| Concept | American | Finnish | Japanese |
|---|---|---|---|
| Green | 1.9 | 1.5 | 1.0 |
| Red | 1.6 | 1.8 | 0.6 |
| Yellow Green | −0.1 | 0.3 | 0.2 |
| Red Purple | 0.1 | 0.2 | −0.3 |
| Star | 2.5 | 2.2 | 1.3 |
| Circle | 2.2 | 2.7 | 2.1 |
| NF #1 | −2.3 | −2.1 | −1.5 |
| NF #2 | −0.6 | 0.1 | −0.5 |

† Plus signs are omitted in the table; minus signs indicate *unfamiliar* while no sign indicates *familiar*.

tically adopted English color names such as *emerald green*, *cobalt green* and *sea green* for the Green color, none of which were given by the English-speaking Americans. Many Japanese color names are of metaphorical nature such as *wakakusa'iro* (fresh-grass color) or *uguisu'iro* (bush-warbler color) for Yellow Green, or *fuji'iro* (westaria color) or *azuki'iro* (azuki-bean color or russet) for Red Purple. On the other hand, both the American and Finnish *Ss* tend to prefix qualifiers such as *dark*, *light*, *pale*, *reddish*, etc., in order to describe different color tones.

Finally, correspondence was tested between the codability and the cognitive familiarity of the eight perceptual signs. If codability is related with cognitive familiarity as proposed by Brown (1958), the mean rating on the *familiar-unfamiliar* scale of each color and form should significantly correspond with the codability of the same defined in the form of $H_{\text{rel}}$, as well. To get at this problem, the mean familiarity score was computed for each concept within each subject group and then they were transformed into polarity scores ranging from $-3$ (i.e., very *unfamiliar*) to $+3$ (i.e., very *familiar*) for appropriate comparisons of concepts. These mean *familiar-unfamiliar* polarity scores are presented in Table 3. In order to examine if codability is significantly correlated with familiarity, a Spearman rank order correlation was computed within each subject group on the basis of the rankings of $H_{\text{rel}}$'s and the rankings of mean familiarity scores across the eight concepts. The $H_{\text{rel}}$'s were ranked from smallest (i.e., most codable) to largest (i.e., least codable) in magnitude, while the mean familiarity polarity scores were ranked from highest positive value (i.e., most familiar) to highest negative value (i.e., most unfamiliar) for each subject group. The rank order correlations thus computed were .95 for the Americans, .91 for the Finns, and .89 for the Japanese, all correlations being significant beyond the .01 level. These high correlations may suggest that highly codable colors and forms tend to be also cognitively more familiar than are low-codable colors and forms in every subject group.

## Summary and Conclusions

A cross-cultural and cross-linguistic experiment was reported in which the codability of eight perceptual signs was examined for three groups of *S*s with contrasting cultural and linguistic backgrounds. The three language/culture groups were American, Finnish and Japanese. The eight perceptual signs used as stimuli in the experiment were two high-codable and two low-codable colors and two high-codable and two low-codable line forms.

In interpreting the results of this study, the reader must be reminded first that the selection of the color and form perceptual signs was dictated by consideration, among other things, of the " congruity " design (see Footnote 2 above), and hence the variety and the number of stimuli actually used in the experiment were relatively restricted. Despite this limitation, however, the results of the present investigation clearly demonstrated that the entropy measure, *H*, is a new adequate index of codability and that it can be applied not only to colors but also to forms, and for the subject groups differing both in culture and in language. It must be pointed out that a cross-cultural or cross-linguistic investigation often involves various imperfections not only with regard to inadequate translations of lexical items, but also because of somewhat different and uncomparable linguistic conventions unique to one language or another. In the present study we thus have found some cross-culturally or cross-linguistically unique labelling behavior for the Japanese. Nonetheless, it also became clear that the *H* measure can be used as a very general associative index and serve for indexing perceptual sign codability despite culture and language differences. It is therefore hoped that the entropy measure, *H*, has proved to have cross-cultural or cross-linguistic validity as a general scientific method and that the results of this relatively restricted study will serve for formulating a better hypothesis and encouraging further research in the area.

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